4 ESTIMATION OF WORST-CASE DISTANCE TO TOXIC ENDPOINT

In Chapter 4

- Reference tables of distances for worst-case releases, including:
  - -- Generic reference tables (Exhibit 2), and
  - -- Chemical-specific reference tables (Exhibit 3).
- Considerations include:
  - -- Gas density (neutrally buoyant or dense),
  - -- Duration of release (10 minutes or 60 minutes),
  - -- Topography (rural or urban).

This guidance provides reference tables giving worst-case distances for neutrally buoyant gases and vapors and for dense gases and vapors for both rural (open) and urban (obstructed) areas. This chapter describes these reference tables and gives instructions to help you choose the appropriate table to estimate consequence distances for the worst-case analysis.

Neutrally buoyant gases and vapors have approximately the same density as air, and dense gases and vapors are heavier than air. Neutrally buoyant and dense gases are dispersed in different ways when they are released; therefore, modeling was carried out to develop separate reference tables. These generic reference tables can be used to estimate distances using the specified toxic endpoint for each substance and the estimated release rate to air. In addition to the generic tables, chemical-specific reference tables are provided for ammonia, chlorine, and sulfur dioxide. These chemical-specific tables were developed based on modeling carried out for industry-specific guidance documents. All the tables were developed assuming a wind speed of 1.5 meters per second (3.4 miles per hour) and F stability. To use the reference tables, you need the worst-case release rates estimated as described in the previous sections. For liquid pool evaporation, you also need the duration of the release. In addition, to use the generic tables, you will need to determine the appropriate toxic endpoint and whether the gas or vapor is neutrally buoyant or dense, using the exhibits in Appendix B. You may interpolate between entries in the reference tables.

Generic reference tables are provided for both 10-minute releases and 60-minute releases. You should use the tables for 10-minute releases if the duration of your release is 10 minutes or less; use the tables for 60-minute releases if the duration of your release is more than 10 minutes. For the worst-case analysis, all releases of toxic gases are assumed to last for 10 minutes. You need to consider the estimated duration of the release (from Equation 3-5) for evaporation of pools of toxic liquids. For evaporation of water solutions of toxic liquids or of oleum, you should always use the tables for 10-minute releases.

The generic reference tables of distances (Reference Tables 1-8), which should be used for substances other than ammonia, chlorine, and sulfur dioxide, are found at the end of Chapter 5. The generic tables and the conditions for which each table are applicable are described in Exhibit 2. Chemical-specific reference tables of distances (Reference Tables 9-12) follow the generic reference tables at the end of Chapter 5. Each of these chemical-specific tables includes distances for both rural and urban topography. These tables are described in Exhibit 3.

Remember that these reference tables provide only rough estimates, not accurate predictions, of the distances that might be reached under worst-case conditions. In particular, although the distances in the tables are as great as 25 miles, you should bear in mind that the larger distances (more than six to ten miles) are very uncertain.

To use the reference tables of distances, follow these steps:

For Regulated Toxic Substances Other than Ammonia, Chlorine, and Sulfur Dioxide

- Find the toxic endpoint for the substance in Appendix B (Exhibit B-1 for toxic gases or Exhibit B-2 for toxic liquids).

- Determine whether the table for neutrally buoyant or dense gases and vapors is appropriate from Appendix B (Exhibit B-1 for toxic gases or Exhibit B-2 for toxic liquids). A toxic gas that is lighter than air may behave as a dense gas upon release if it is liquefied under pressure, because the released gas may be mixed with liquid droplets, or if it is cold. Consider the state of the released gas when you decide which table is appropriate.

- Determine whether the table for rural or urban conditions is appropriate.

  -- Use the rural table if your site is in an open area with few obstructions.

  -- Use the urban table if your site is in an urban or obstructed area. The urban tables are appropriate if there are many obstructions in the area, even if it is in a remote location, not in a city.

- Determine whether the 10-minute table or the 60-minute table is appropriate.

  -- Always use the 10-minute table for worst-case releases of toxic gases.

  -- Always use the 10-minute table for worst-case releases of common water solutions and oleum from evaporating pools, for both ambient and elevated temperatures.

  -- If you estimated the release duration for an evaporating toxic liquid pool to be 10 minutes or less, use the 10-minute table.

  -- If you estimated the release duration for an evaporating toxic liquid pool to be more than 10 minutes, use the 60-minute table.

Exhibit 2
Generic Reference Tables of Distances for Worst-case Scenarios

Applicable Conditions			Reference Table Number
Gas or Vapor Density	**Topography**	**Release Duration (minutes)**	
Neutrally buoyant	Rural	10	1
		60	2
	Urban	10	3
		60	4
Dense	Rural	10	5
		60	6
	Urban	10	7
		60	8

Exhibit 3
Chemical-Specific Reference Tables of Distances for Worst-case Scenarios

Substance	Applicable Conditions			Reference Table Number
	Gas or Vapor Density	**Topography**	**Release Duration (minutes)**	
Anhydrous ammonia liquefied under pressure	Dense	Rural, Urban	10	9
Non-liquefied ammonia, ammonia liquefied by refrigeration, or aqueous ammonia	Neutrally buoyant	Rural, Urban	10	10
Chlorine	Dense	Rural, Urban	10	11
Sulfur dioxide (anhydrous)	Dense	Rural, Urban	10	12

Neutrally Buoyant Gases or Vapors

- If Exhibit B-1 or B-2 indicates the gas or vapor should be considered neutrally buoyant, and other factors would not cause the gas or vapor to behave as a dense gas, divide the estimated release rate (pounds per minute) by the toxic endpoint (milligrams per liter).

- Find the range of release rate/toxic endpoint values that includes your calculated release rate/toxic endpoint in the first column of the appropriate table (Reference Table 1, 2, 3, or 4), then find the corresponding distance to the right (see Example 13 below).

Dense Gases or Vapors

- If Exhibit B-1 or B-2 or consideration of other relevant factors indicates the substance should be considered a dense gas or vapor (heavier than air), find the distance in the appropriate table (Reference Table 5, 6, 7, or 8) as follows;

  -- Find the toxic endpoint closest to that of the substance by reading across the top of the table. If the endpoint of the substance is halfway between two values on the table, choose the value on the table that is smaller (to the left). Otherwise, choose the closest value to the right or the left.

  -- Find the release rate closest to the release rate estimated for the substance at the left of the table. If the calculated release rate is halfway between two values on the table, choose the release rate that is larger (farther down on the table). Otherwise, choose the closest value (up or down on the table).

  -- Read across from the release rate and down from the endpoint to find the distance corresponding to the toxic endpoint and release rate for your substance.

For Ammonia, Chlorine, or Sulfur Dioxide

- Find the appropriate chemical-specific table for your substance (see the descriptions of Reference Tables 9-12 in Exhibit 3).

  -- If you have ammonia liquefied by refrigeration alone, you may use Reference Table 10, even if the duration of the release is greater than 10 minutes.

  -- If you have chlorine or sulfur dioxide liquefied by refrigeration alone, you may use the chemical-specific reference tables, even if the duration of the release is greater than 10 minutes.

- Determine whether rural or urban topography is applicable to your site.

  -- Use the rural column in the reference table if your site is in an open area with few obstructions.

-- Use the urban column if your site is in an urban or obstructed area. The urban column is appropriate if there are many obstructions in the area, even if it is in a remote location, not in a city.

- Estimate the consequence distance as follows:

  -- In the left-hand column of the table, find the release rate closest to your calculated release rate.

  -- Read the corresponding distance from the appropriate column (urban or rural) to the right.

The development of Reference Tables 1-8 is discussed in Appendix D, Sections D.4.1 and D.4.2. The development of Reference Tables 9-12 is discussed in industry-specific risk management program guidance documents and a backup information document that are cited in Section D.4.3. If you think the results of the method presented here overstate the potential consequences of a worst-case release at your site, you may choose to use other methods or models that take additional site-specific factors into account.

Examples 14 and 15 below include the results of modeling using two other models, the Areal Locations of Hazardous Atmospheres (ALOHA) and the World Bank Hazards Analysis (WHAZAN) systems. These additional results are provided for comparison with the results of the methods presented in this guidance. The same modeling parameters were used as in the modeling carried out for development of the reference tables of distances. Appendix D, Section D.4.5, provides information on the modeling carried out with ALOHA and WHAZAN.

Example 13. Gas Release (Diborane)

In Example 1, you estimated a release rate for diborane gas of 250 pounds per minute. From Exhibit B-1, the toxic endpoint for diborane is 0.0011 mg/L, and the appropriate reference table for diborane is a neutrally buoyant gas table. Your facility and the surrounding area have many buildings, pieces of equipment, and other obstructions; therefore, you assume urban conditions. The appropriate reference table is Reference Table 3, for a 10-minute release of a neutrally buoyant gas in an urban area.

The release rate divided by toxic endpoint for this example is 250/0.0011 = 230,000.

From Reference Table 3, release rate divided by toxic endpoint falls between 221,000 and 264,000, corresponding to about 8.1 miles.

Example 14. Gas Release (Ethylene Oxide)

You have a tank containing 10,000 pounds of ethylene oxide, which is a gas under ambient conditions. Assuming the total quantity in the tank is released over a 10-minute period, the release rate (QR) from Equation 3-1 is:

QR = 10,000 pounds/10 minutes = 1,000 pounds per minute

From Exhibit B-1, the toxic endpoint for ethylene oxide is 0.09 mg/L, and the appropriate reference table is the dense gas table. Your facility is in an open, rural area with few obstructions; therefore, you use the table for rural areas.

Using Reference Table 5 for 10-minute releases of dense gases in rural areas, the toxic endpoint of 0.09 mg/L is closer to 0.1 than 0.075 mg/L. For a release rate of 1,000 pounds per minute, the distance to 0.1 mg/L is 3.6 miles.

Additional Modeling for Comparison

The ALOHA model gave a distance of 2.2 miles to the endpoint, using the same assumptions.

The WHAZAN model gave a distance of 2.7 miles to the endpoint, using the same assumptions and the dense cloud dispersion model.

Example 15. Liquid Evaporation from Pool (Acrylonitrile)

You estimated an evaporation rate of 307 pounds per minute for acrylonitrile from a pool formed by the release of 20,000 pounds into an undiked area (Example 4). You estimated the time for evaporation of the pool as 65 minutes. From Exhibit B-2, the toxic endpoint for acrylonitrile is 0.076 mg/L, and the appropriate reference table for a worst-case release of acrylonitrile is the dense gas table. Your facility is in an urban area. You use Reference Table 8 for 60-minute releases of dense gases in urban areas.

From Reference Table 8, the toxic endpoint closest to 0.076 mg/L is 0.075 mg/L, and the closest release rate to 307 pounds per minute is 250 pounds per minute. Using these values, the table gives a worst-case consequence distance of 2.9 miles.

Additional Modeling for Comparison

The ALOHA model gave a distance of 1.3 miles to the endpoint for a release rate of 307 pounds per minute, using the same assumptions.

The WHAZAN model gave a distance of 1.0 mile to the endpoint for a release rate of 307 pounds per minute, using the same assumptions and the dense cloud dispersion model.